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(71) Applicants:
- **Elettronica Santerno S.p.A.**
40020 Casalfiumanese (IT)
- **Zanarini, Sergio**
40020 Casalfiumanese (IT)

(72) Inventor: **Zanarini, Sergio**
40020 Casalfuimanese (IT)

(74) Representative: **Bongiovanni, Simone (IT) et al**
Studio Torta S.r.l
Via Viotti 9
I-10121 Torino (IT)

(54) System for the production and controlled distribution of electric energy in isolated areas

(57) A system (1) for the production and controlled distribution of electric energy in isolated areas, having a rotary electric generator (5) for producing electric energy, and an internal combustion engine (6) for powering the electric generator (5); the system (1) being characterized by having an energy switching node (7) to which at least one electric energy user (4) is connectable electrically; the energy switching node (7) having electric power draw measuring means (12) for determining, instant by instant, the electric power drawn by the electric energy user (4), and electric energy supply cutoff means (13) for cutting off, on command, electric energy supply to the electric energy user (4); the system (1) also having electric energy supply control means (23) for controlling electric energy supply to users, and which meter the consumption of the electric energy user (4) instant by instant on the basis of the findings of the electric power draw measuring means (12), and activate the electric energy supply cutoff means (13) to cut off energy supply when the consumption credit of the electric energy user (4) runs out.

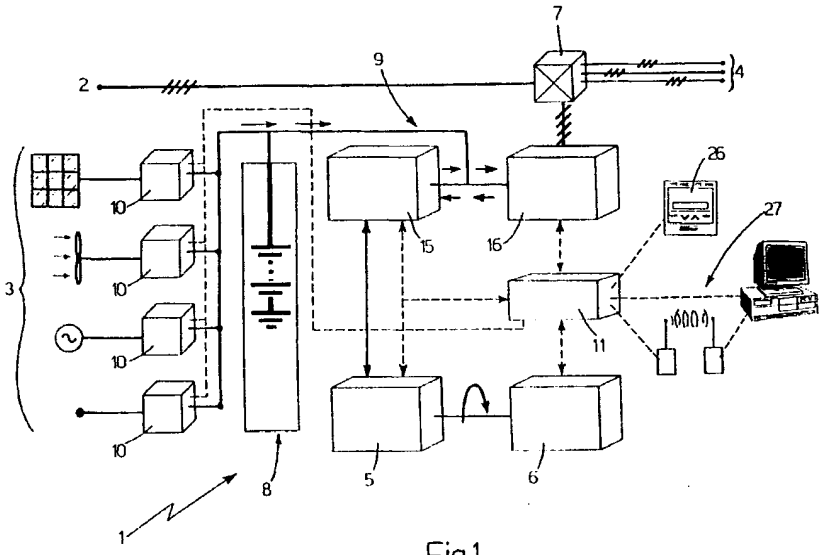

Fig.1

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Description

[0001] The present invention relates to a system for the production and controlled distribution of electric energy in isolated areas.

[0002] As is known, in recent years, a considerable increase has been recorded in the demand for small- and medium-power generator sets for supplying - in parallel with discontinuous electric energy sources, such as solar panels or wind generators - rural areas that cannot be serviced by conventional electricity mains. It is far more economical, in fact, to produce electric energy locally using conventional fuel than to construct long power lines connecting major power plants to isolated communities.

[0003] Currently used generator sets comprise a synchronous electric generator; an internal combustion drive unit (normally a diesel engine) for driving the electric generator; and a control unit for starting and so controlling the drive unit as to operate the electric generator at a constant predetermined rotation speed depending on the frequency of the electricity mains replaced. The rotary electric generator is normally installed in parallel with discontinuous electric energy sources, so as to supply users, as required, with electric energy in conjunction with or in lieu of the discontinuous electric energy sources.

[0004] Given the high cost of generator sets and the fact that they are normally used in developing countries with limited funds, increased demand has also led to the setting up of numerous companies, which purchase and install generator sets - possibly together with other discontinuous electric energy sources - close to and for marketing electric energy to populated areas not serviced by conventional electricity mains.

[0005] Known generator sets, however, are unsuitable for this purpose by failing to control, instant by instant, how much electric energy is and/or has been supplied to each user, who is therefore billed periodically by the company for a lump sum which often bears no relation to actual consumption. In many cases, in fact, the user may be billed so disproportionately as to revert to alternative makeshift solutions.

[0006] Known generator sets also have the major drawback of not being integratable with other electric energy sources to optimize production and distribution of the electric energy available.

[0007] It is an object of the present invention to provide a system for the production and controlled distribution of electric energy in isolated areas, designed to eliminate the drawbacks of conventional generator sets, and which, at the same time, is flexible, reliable and cheap to run.

[0008] According to the present invention, there is provided a system for the production and controlled distribution of electric energy in isolated areas, comprising a rotary electric generator for producing electric energy, and an internal combustion engine for powering said electric generator; said system being characterized by comprising an energy switching node to which at least one electric energy user is connectable electrically; said energy switching node having electric power draw measuring means for determining, instant by instant, the electric power drawn by said electric energy user, and electric energy supply cutoff means for cutting off, on command, electric energy supply to said electric energy user; said system also comprising electric energy supply control means for controlling electric energy supply to users, and which meter the consumption of said electric energy user instant by instant on the basis of the findings of the electric power draw measuring means, and activate the electric energy supply cutoff means to cut off energy supply when the consumption credit of said electric energy user runs out.

[0009] A non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows schematically a system for the production and controlled distribution of electric energy in isolated areas, in accordance with the teachings of the present invention;

Figures 2 and 3 show two schematic details of the Figure 1 system.

[0010] Number 1 in Figure 1 indicates as a whole a system for the production and controlled distribution of electric energy, and which is especially suitable for use in rural or isolated areas possibly also equipped with discontinuous electric energy sources, such as solar panels, wind generators, small hydraulic turbines, or even an electricity mains unable to ensure continuous electric energy supply.

[0011] In the following description, the electricity mains supplying electric energy discontinuously with a mains frequency f is indicated 2, and the other discontinuous electric energy sources, i.e. alternative electric energy sources such as solar panels, wind generators, small hydraulic turbines, etc., are indicated as a whole by 3.

[0012] With reference to Figure 1, system 1 is interposed between the discontinuous electric energy sources - i.e. electricity mains 2, if any, and alternative electric energy sources 3 - and one or more electric energy users 4. In the example shown, reference is made to three electric energy users 4.

[0013] System 1 comprises a known rotary electric generator 5 for producing electric energy with a mains frequency varying according to the rotation speed of the generator; an internal combustion engine 6 for rotating the shaft of electric generator 5 at a speed variable in any manner to produce electric energy; and an energy switching node 7 to which electricity mains 2, if any, and the three electric energy users 4 are connected directly.

[0014] System 1 also comprises an electric energy storage battery 8; a two-way electric energy static con-

version unit 9 connecting electric energy storage battery 8 to electric generator 5 and energy switching node 7; and one or more one-way electric energy static conversion units 10 connecting electric energy source/s 3 to electric energy storage battery 8.

[0015] Static conversion unit 9 controls electric energy supply to and from electric generator 5 and energy switching node 7; and static conversion unit/s 10 control electric energy supply from electric energy source/s 3 to electric energy storage battery 8.

[0016] System 1 also comprises a control unit 11 for controlling static conversion unit 9, static conversion unit/s 10, internal combustion engine 6 and energy switching node 7 according to a predetermined logic and as a function of various detected operating parameters, so as make the best use of available resources and maximize the overall efficiency of system 1.

[0017] In the example shown, electricity mains 2 is a three-phase type with a mains frequency f; the three electric energy users 4 draw three-phase electric energy; electric generator 5 is a three-phase asynchronous motor-generator; and internal combustion engine 6 is a diesel engine. Electric generator 5 may, obviously, also be defined by a known synchronous generator.

[0018] Electric energy storage battery 8 is capable of storing electric energy in another form (e.g. kinetic or chemical energy) and is defined, in the example shown, by a series of known rechargeable lead-acid batteries.

[0019] Under the control of control unit 11, energy switching node 7 controls the electric connections between electricity mains 2 and static conversion unit 9 to allow each electric energy user 4 to draw electric energy with mains frequency f, regardless of the presence or not of electric energy in electricity mains 2. Again under the control of control unit 11, energy switching node 7 also monitors electric energy supply to each electric energy user 4, and, on command, cuts off the electric connection between electric energy user 4 and the currently operating electric energy source, be it electricity mains 2 or static conversion unit 9.

[0020] With reference to Figure 2, energy switching node 7 comprises, for each electric energy user 4, a controlled electric switch 12 for selectively connecting electric energy user 4 electrically to electricity mains 2 and static conversion unit 9; and an electric power measuring device 13 located in series with controlled electric switch 12, and which provides for determining, instant by instant, the amount of electric energy drawn per unit of time by electric energy user 4, and for communicating the findings to control unit 11.

[0021] Preferably, though not necessarily, energy switching node 7 has known directional safeguards for selectively isolating electricity mains 2 from static conversion unit 9 when electricity mains 2 is unable to supply electric energy and electric energy users 4 are supplied with electric energy by static conversion unit 9.

[0022] With reference to Figure 1, static conversion unit 9 comprises two known impressed-voltage conversion bridges, a first of which, indicated 15, connects electric energy storage battery 8 to electric generator 5 and permits electric energy supply to and from electric generator 5, and a second of which, indicated 16, connects electric energy storage battery 8 to energy switching node 7 and permits electric energy supply to and from energy switching node 7. Conversion bridges 15 and 16, which are three-phase in the example shown, are controlled by control unit 11 and preferably, though not necessarily, operate in PWM (Pulse Width Modulation) mode.

[0023] More specifically, conversion bridge 15 is capable of both converting electric energy with any mains frequency into direct electric energy to permit electric energy supply from electric generator 5 to electric energy storage battery 8, and converting direct electric energy into electric energy with any mains frequency to permit electric energy supply from electric energy storage battery 8 to electric generator 5. In the first case, electric generator 5 performs its main function, which is that of producing electric energy for supply to electric energy storage battery 8; and, in the second case, electric generator 5 is used as a starting motor to start internal combustion engine 6, which, as is known, has zero starting torque.

[0024] Similarly, conversion bridge 16 is capable of both converting direct electric energy into electric energy with mains frequency f to permit electric energy supply from electric energy storage battery 8 to energy switching node 7, and converting the electric energy with mains frequency f from electricity mains 2 into direct electric energy to permit electric energy supply from energy switching node 7 to electric energy storage battery 8.

[0025] The or each static conversion unit 10 is defined by a conversion bridge capable of converting the electric energy produced by electric energy source 3 - be it direct or alternating with a fixed or variable frequency - into direct electric energy to permit electric energy supply from electric energy source 3 to electric energy storage battery 8. Obviously, the characteristics of the conversion bridge depend on the type of electric energy produced by electric energy source 3.

[0026] With reference to Figures 1 and 3, control unit 11 comprises an electronic central control unit 18 for real-time controlling conversion bridges 15 and 16; an electronic central control unit 19 for real-time controlling static conversion unit/s 10; an electronic central monitoring unit 20 for monitoring and coordinating the electric energy supplies produced by electronic central control units 18 and 19; an electronic central control unit 21 for controlling internal combustion engine 6; and a main electronic central control unit 22 for overall control of system 1 as a function of signals from a number of sensors (not shown) distributed throughout system 1 and for detecting, for example, the voltages of electricity mains 2, energy switching node 7 and electric energy sources 3, the electric energy to and from energy switch-

ing node 7 per unit of time, the rotation speed of internal combustion engine 6, i.e. of electric generator 5, and the amount of electric energy stored in electric energy storage battery 8.

[0027] Control unit 11 also comprises an electronic central control unit 23 for controlling energy switching node 7 and electric energy supply to users, and which receives the signals from the various electric power measuring devices 13, meters instant by instant the consumption of each electric energy user 4, and disconnects the user from energy switching node 7 upon consumption exceeding a predetermined prepaid amount, i.e. when the prepaid consumption credit of electric energy user 4 runs out. Electric energy user 4 is obviously disconnected by opening the corresponding controlled electric switch 12.

[0028] To simplify consumption control, control unit 11 is also provided with one or more credit terminals 24 located close to system 1 and in the immediate vicinity of electric energy user/s 4 to enable any user connected to system 1 to take out further prepaid consumption credit. In a further embodiment, credit terminal 24 may be defined by a known cellular telephone.

[0029] Credit terminals 24 are obviously connected to electronic central control unit 23 to transmit to it in real time the particulars of the electric energy user 4 taking out further prepaid consumption credit and the amount of credit taken out, and comprise collecting means for receiving and verifying paper money, credit cards and similar.

[0030] In the example shown, control unit 11 also comprises a known chronological event recorder 25 for sequentially storing, for a given length of time, the signals from the sensors (not shown) and electronic central control units 18, 19, 20, 21, 21, to immediately detect any malfunctions.

[0031] Control unit 11 also comprises an operator control panel 26 for directly controlling electronic central control unit 22 and, hence, system 1; and a known communications network 27 by which electronic central control unit 22 communicates with an external control station even a considerable distance from the system. Communications network 27 may also be used to connect the control units 11, and so permit parallel operation, of a number of systems similar to system 1.

[0032] Electronic central control unit 22 controls the production and supply of electric energy according to various criteria, including the amount and cost of electric energy available from electricity mains 2, the electric energy available from alternative electric energy sources 3, electric energy demand by electric energy users 4, and the cost of producing electric energy by means of electric generator 5.

[0033] More specifically, electronic central control unit 22 controls energy switching node 7 to appropriately connect electricity mains 2, electric energy users 4 and conversion unit 9, and also controls start-up and the speed of internal combustion engine 6 as a function of electric energy production requirements.

[0034] More specifically, electronic central control unit 22 may control electric energy supply to supply electric energy users 4 with electric energy from electric generator 5 and/or electric energy storage battery 8, when no electric energy is available from electricity mains 2 (if present) or alternative electric energy sources 3; or may control electric energy supply to supply electric energy users 4 with electric energy from one or more alternative electric energy sources 3 and possibly also from electric energy storage battery 8, when no electric energy is available from electricity mains 2 (if present) and operating electric generator 5 is uneconomical.

[0035] Other operating combinations are obviously possible, depending on the electric energy sources available and the energy demand of users 4.

[0036] It should be pointed out that, when electric energy storage battery 8 is fully charged, electronic central control unit 22 is capable of controlling and balancing electric energy supply to and from electric energy storage battery 8 to avoid overloading the battery.

[0037] When necessary, electronic central control unit 22 can use the electric energy from electricity mains 2 to both supply electric energy users 4 and recharge electric energy storage battery 8.

[0038] Operation of system 1 is easily deducible from the above description with no further explanation required.

[0039] It should be pointed out, however, that operation of the assembly defined by electric generator 5 and internal combustion engine 6 differs from that of known no-break systems by the speed of internal combustion engine 6, i.e. of electric generator 5, varying as a function of electric energy demand per unit of time, as opposed to being determined as a function of the frequency of the electric energy supplied, i.e. mains frequency f.

[0040] System 1 for the production and controlled distribution of electric energy in isolated areas, as described above, has numerous advantages: first and foremost is undoubtedly the flexibility with which the system caters to the energy requirements of each electric energy user 4. Using system 1, the consumption of each electric energy user 4 can be programmed, in terms of when and how much, according to personal finances.

[0041] Other major advantages of system 1 are the high degree of overall efficiency by employing at any time the cheapest source of electric energy, be it electricity mains 2, electric generator 5, or any of alternative electric energy sources 3; and the high degree of flexibility in the operation of the system which enables it to adapt in real time to the electric energy requirements of electric energy users 4.

[0042] A further advantage of system 1 is the possibility of employing the electric energy from electricity mains 2 (if present), from alternative electric energy sources 3, from electric generator 5 and from electric energy storage battery 8 jointly to meet any peak demand by electric energy users 4.

[0043] A major advantage of using an asynchronous motor-generator such as electric generator 5 is that of eliminating the need for a starting motor for internal combustion engine 6.

[0044] Clearly, changes may be made to system 1 for the production and controlled distribution of electric energy in isolated areas, as described and illustrated herein, without, however, departing from the scope of the present invention.

Claims

1. A system (1) for the production and controlled distribution of electric energy in isolated areas, comprising a rotary electric generator (5) for producing electric energy, and an internal combustion engine (6) for powering said electric generator (5); said system (1) being **characterized by** comprising an energy switching node (7) to which at least one electric energy user (4) is connectable electrically; said energy switching node (7) having electric power draw measuring means (12) for determining, instant by instant, the electric power drawn by said electric energy user (4), and electric energy supply cutoff means (13) for cutting off, on command, electric energy supply to said electric energy user (4); said system (1) also comprising electric energy supply control means (23) for controlling electric energy supply to users, and which meter the consumption of said electric energy user (4) instant by instant on the basis of the findings of the electric power draw measuring means (12), and activate the electric energy supply cutoff means (13) to cut off energy supply when the consumption credit of said electric energy user (4) runs out.

2. A system as claimed in Claim 1, **characterized by** comprising at least one credit terminal (24) permitting said at least one electric energy user (4) to purchase further consumption credit; said at least one credit terminal (24) being connected to said electric energy supply control means (23).

3. A system as claimed in Claim 1 or 2, **characterized in that** said electric energy supply cutoff means (13) comprise at least one controlled electric switch (13) upstream from said electric energy user (4).

4. A system as claimed in Claim 3, **characterized in that** said electric power draw measuring means (12) comprise at least one electric power measuring device (12) in series with said controlled electric switch (13).

5. A system as claimed in any one of the foregoing Claims, **characterized by** comprising an electric energy storage battery (8), and a first static electric energy conversion unit (9) connecting the electric energy storage battery (8) to the electric generator (5) and to said energy switching node (7); said first static electric energy conversion unit (9) controlling electric energy supply to and from the electric generator (5) and the energy switching node (7).

6. A system as claimed in Claim 5, **characterized by** comprising at least one discontinuous electric energy source (2, 3), and at least one second static electric energy conversion unit (10) connecting said discontinuous electric energy source (3) to said electric energy storage battery (8); said second static electric energy conversion unit (10) controlling electric energy supply from the discontinuous electric energy source (2, 3) to the electric energy storage battery (8).

7. A system as claimed in Claim 6, **characterized by** comprising a control unit (11) for controlling, according to a predetermined logic, said first static electric energy conversion unit (9), said second static electric energy conversion unit (10), the internal combustion engine (6) and the energy switching node (7) as a function of various detected operating parameters, so as to make the best use of the various resources available and maximize overall efficiency of the system (1).

8. A system as claimed in Claim 7, **characterized in that** said first static electric energy conversion unit (9) is two-way and comprises two conversion bridges (15, 16), a first of which connects the electric energy storage battery (8) to the electric generator (5) and permits electric energy supply to and from the electric generator (5), and a second of which connects the electric energy storage battery (8) to the energy switching node (7) and permits electric energy supply to and from the energy switching node (7).

9. A system as claimed in Claim 8, **characterized in that** said second static electric energy conversion unit (10) is one-way and defined by a conversion bridge for converting the electric energy produced by the discontinuous electric energy source (2, 3) into electric energy suitable for the electric energy storage battery (8), so as to permit electric energy supply from said discontinuous electric energy source (2, 3) to said electric energy storage battery (8).

10. A system as claimed in any one of Claims 5 to 9, **characterized in that** said at least one discontinuous electric energy source (2, 3) comprises an electricity mains (2) supplying electric energy discontinuously at a constant mains frequency (f); said electricity mains (2) being connected directly to said en-

ergy switching node (7).

11. A system as claimed in any one of the foregoing Claims, **characterized in that** said electric generator (5) is an asynchronous motor-generator.

12. A system as claimed in any one of Claims 6 to 11, **characterized in that** said control unit (11) comprises a communications network (27) by which a main electronic central control unit (22) communicates with an external control station.

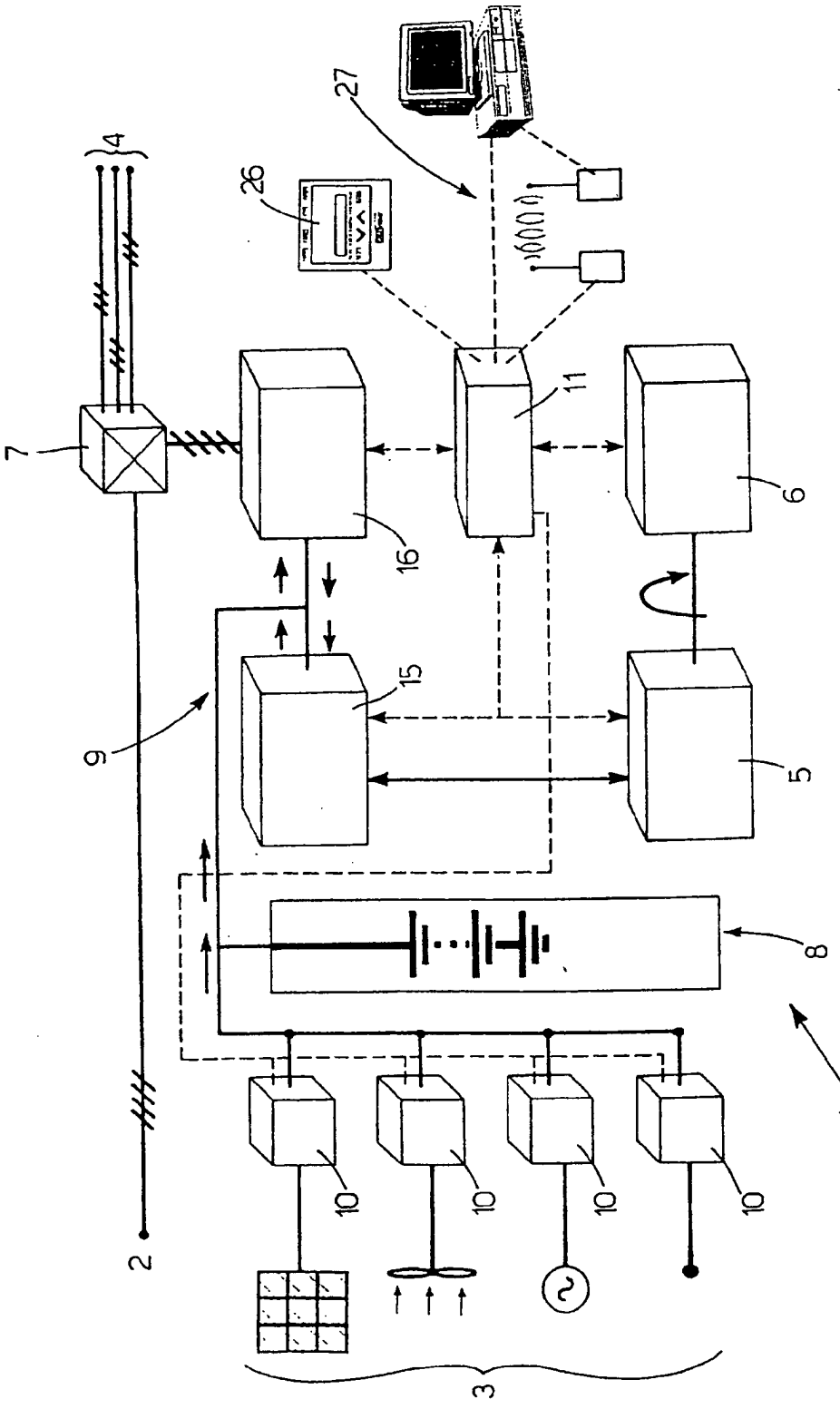

Fig.1

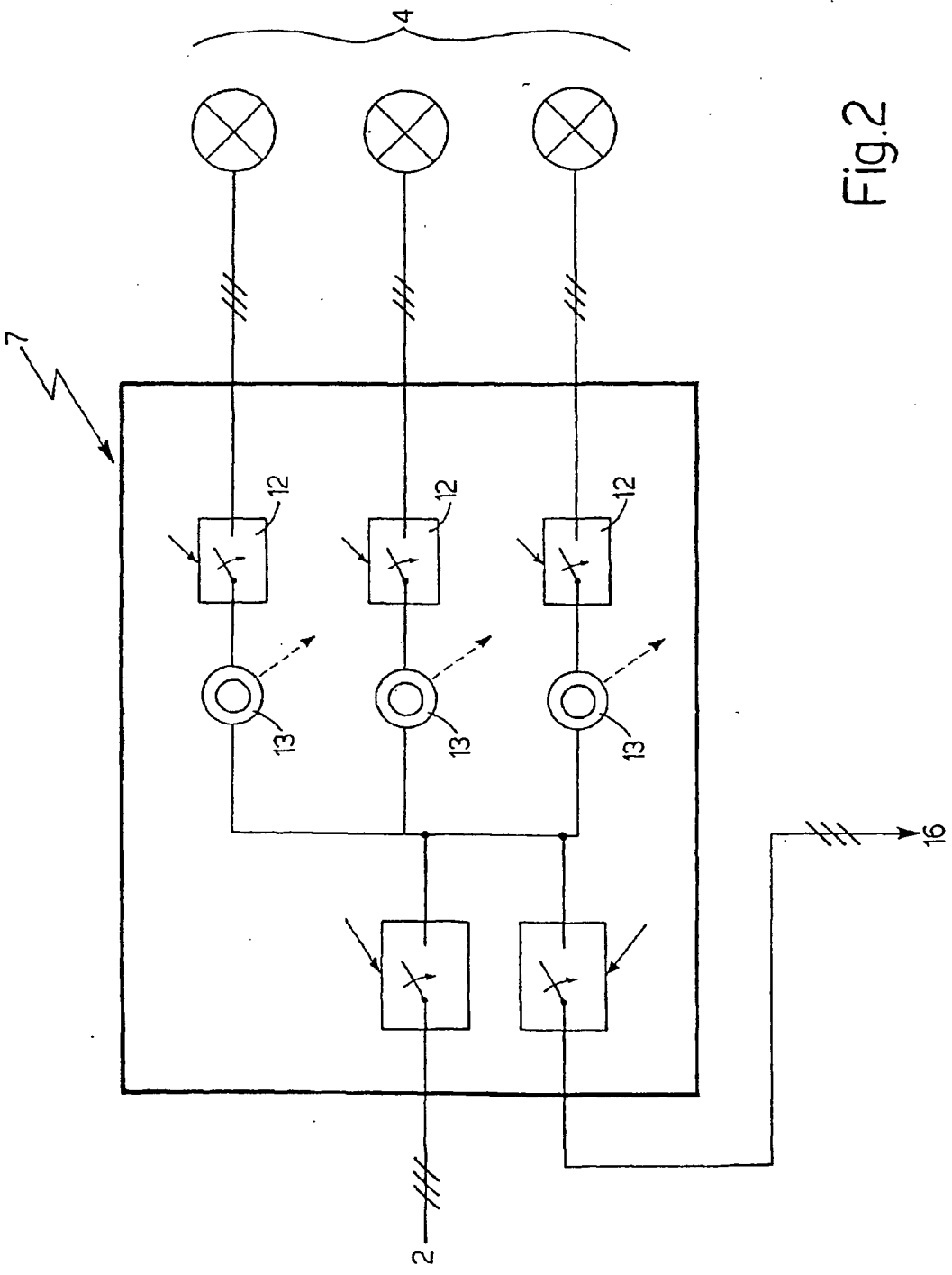

Fig.2